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New specification part

(replace pp. 1 and 2 of the original specification)

ELECTRONICALLY COMMUTATABLE MOTOR

Background Information

The present invention relates to an electronically commutatable motor, whose excitation windings are controllable via semiconductor output stages by an electronic control unit with the aid of PWM control signals, a setpoint value being specifiable to the control unit, and the control unit emitting corresponding PWM control signals to the semiconductor output stages; a motor characteristic curve, from which an assigned nominal operating speed is derivable for the setpoint value, being stored in the control unit, and the derived nominal operating speed being able to be compared to the actual speed of the motor, and if a predefinable or predefined speed difference between the nominal operating speed and the actual speed is exceeded, the control unit and/or the semiconductor output stages is/are able to be switched off.

Such a motor is known from the German Patent 195 04 874 A1. In that case, the PWM control signals are established in their pulse width by the input of the setpoint value. The comparison of the nominal operating speed, which is assigned to the setpoint value, to the actual speed is used during the continuous running

of the motor to determine whether the motor

load and the setpoint value, it requires a considerable expenditure of memory in the control unit to ascertain the allocated nominal operating speed for the comparison to the actual speed, i.e. for the monitoring of the motor.

5 To store the characteristic-curve data of a motor in a memory of the control unit and to use the characteristic-curve data for deriving an operating value is also known from the U.S. Patent 5,901,236 and from EP-A 0 386 057. In that case, as a rule, a characteristics field having a plurality of value pairs is used, from which the desired nominal operating value can be derived by interpolation onto a third coordinate. 10 However, this requires a considerable expenditure of memory, particularly when the load of the motor also changes.

15 The object of the present invention is to provide a motor of the type mentioned at the outset with simple data in the control unit, which, with minimal expenditure, for a predefined load, significantly simplifies the derivation of the nominal operating speed corresponding to a predefined setpoint value.

20 This objective is achieved according to the present invention, in that the motor characteristic curve is stored as a characteristics field having four three-dimensional corner points; in the x-axis, the limiting values of the supply voltage, and in the z-axis, the limiting values of the PWM control signals determine 25 the nominal operating speed.

The characteristics field permits the formation of a map from

which, for an existing supply voltage and a PWM control signal corresponding to the predefined setpoint value, the allocated nominal operating speed is derivable for the comparison with the measured actual speed.

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In this context, advantage is taken of the fact that in many cases, the motor is always loaded with the same consumer, such as in the case of a fan drive. The four....

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sought nominal operating speed (in the y-direction).

Depending upon the use of the motor, according to a further embodiment, the four corner points of the
5 characteristics field may be determined for a predefined motor load. The motor can then be designed in a simple manner for a different load, i.e. consumer.

In this context, according to one refinement, the
10 comparison between the nominal operating speed and the actual speed is able to be carried out continually during the continuous running of the motor or repeated at time intervals.

15 The setpoint value may be specifiable manually in a simple manner using a potentiometer, the control unit being able to be supplied with a more or less large setting signal which is used for the emission of allocated PWM control signals for the semiconductor
20 output stages. In addition, using this setting signal, the allocated nominal operating speed may be derived on the basis of the stored motor characteristic curve and utilized for the comparison with the actual speed of the motor arising. The actual speed of the motor may be
25 detected in different ways which are also known.

For the comparison of the nominal operating speed and the actual speed, the control unit is preferably assigned a
30 comparator unit which, by preference, is integrated into the control unit.

Such a device is described in the German patent application

50 2,631,832, the content of which is incorporated herein by reference.
The invention also relates to a method for the control of a motor, the
55 motor having a commutator or a brushless motor, the method comprising the steps of:
determining the sought nominal operating speed (in the y-direction);
determining the four corner points of the characteristics field; and
utilizing the four corner points of the characteristics field to determine the
60 allocated PWM control signals for the semiconductor output stages.

55 65 70 75 80 85 90 95 100 105 110 115 120 125 130 135 140 145 150 155 160 165 170 175 180 185 190 195 200 205 210 215 220 225 230 235 240 245 250 255 260 265 270 275 280 285 290 295 300 305 310 315 320 325 330 335 340 345 350 355 360 365 370 375 380 385 390 395 400 405 410 415 420 425 430 435 440 445 450 455 460 465 470 475 480 485 490 495 500 505 510 515 520 525 530 535 540 545 550 555 560 565 570 575 580 585 590 595 600 605 610 615 620 625 630 635 640 645 650 655 660 665 670 675 680 685 690 695 700 705 710 715 720 725 730 735 740 745 750 755 760 765 770 775 780 785 790 795 800 805 810 815 820 825 830 835 840 845 850 855 860 865 870 875 880 885 890 895 900 905 910 915 920 925 930 935 940 945 950 955 960 965 970 975 980 985 990 995 1000 1005 1010 1015 1020 1025 1030 1035 1040 1045 1050 1055 1060 1065 1070 1075 1080 1085 1090 1095 1100 1105 1110 1115 1120 1125 1130 1135 1140 1145 1150 1155 1160 1165 1170 1175 1180 1185 1190 1195 1200 1205 1210 1215 1220 1225 1230 1235 1240 1245 1250 1255 1260 1265 1270 1275 1280 1285 1290 1295 1300 1305 1310 1315 1320 1325 1330 1335 1340 1345 1350 1355 1360 1365 1370 1375 1380 1385 1390 1395 1400 1405 1410 1415 1420 1425 1430 1435 1440 1445 1450 1455 1460 1465 1470 1475 1480 1485 1490 1495 1500 1505 1510 1515 1520 1525 1530 1535 1540 1545 1550 1555 1560 1565 1570 1575 1580 1585 1590 1595 1600 1605 1610 1615 1620 1625 1630 1635 1640 1645 1650 1655 1660 1665 1670 1675 1680 1685 1690 1695 1700 1705 1710 1715 1720 1725 1730 1735 1740 1745 1750 1755 1760 1765 1770 1775 1780 1785 1790 1795 1800 1805 1810 1815 1820 1825 1830 1835 1840 1845 1850 1855 1860 1865 1870 1875 1880 1885 1890 1895 1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070 2075 2080 2085 2090 2095 2100 2105 2110 2115 2120 2125 2130 2135 2140 2145 2150 2155 2160 2165 2170 2175 2180 2185 2190 2195 2200 2205 2210 2215 2220 2225 2230 2235 2240 2245 2250 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5255 5260 5265 5270 5275 5280 5285 5290 5295 5300 5305 5310 5315 5320 5325 5330 5335 5340 5345 5350 5355 5360 5365 5370 5375 5380 5385 5390 5395 5400 5405 5410 5415 5420 5425 5430 5435 5440 5445 5450 5455 5460 5465 5470 5475 5480 5485 5490 5495 5500 5505 5510 5515 5520 5525 5530 5535 5540 5545 5550 5555 5560 5565 5570 5575 5580 5585 5590 5595 5600 5605 5610 5615 5620 5625 5630 5635 5640 5645 5650 5655 5660 5665 5670 5675 5680 5685 5690 5695 5700 5705 5710 5715 5720 5725 5730 5735 5740 5745 5750 5755 5760 5765 5770 5775 5780 5785 5790 5795 5800 5805 5810 5815 5820 5825 5830 5835 5840 5845 5850 5855 5860 5865 5870 5875 5880 5885 5890 5895 5900 5905 5910 5915 5920 5925 5930 5935 5940 5945 5950 5955 5960 5965 5970 5975 5980 5985 5990 5995 6000 6005 6010 6015 6020 6025 6030 6035 6040 6045 6050 6055 6060 6065 6070 6075 6080 6085 6090 6095 6100 6105 6110 6115 6120 6125 6130 6135 6140 6145 6150 6155 6160 6165 6170 6175 6180 6185 6190 6195 6200 6205 6210 6215 6220 6225 6230 6235 6240 6245 6250 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8255 8260 8265 8270 8275 8280 8285 8290 8295 8300 8305 8310 8315 8320 8325 8330 8335 8340 8345 8350 8355 8360 8365 8370 8375 8380 8385 8390 8395 8400 8405 8410 8415 8420 8425 8430 8435 8440 8445 8450 8455 8460 8465 8470 8475 8480 8485 8490 8495 8500 8505 8510 8515 8520 8525 8530 8535 8540 8545 8550 8555 8560 8565 8570 8575 8580 8585 8590 8595 8600 8605 8610 8615 8620 8625 8630 8635 8640 8645 8650 8655 8660 8665 8670 8675 8680 8685 8690 8695 8700 8705 8710 8715 8720 8725 8730 8735 8740 8745 8750 8755 8760 8765 8770 8775 8780 8785 8790 8795 8800 8805 8810 8815 8820 8825 8830 8835 8840 8845 8850 8855 8860 8865 8870 8875 8880 8885 8890 8895 8900 8905 8910 8915 8920 8925 8930 8935 8940 8945 8950 8955 8960 8965 8970 8975 8980 8985 8990 8995 9000 9005 9010 9015 9020 9025 9030 9035 9040 9045 9050 9055 9060 9065 9070 9075 9080 9085 9090 9095 9100 9105 9110 9115 9120 9125 9130 9135 9140 9145 9150 9155 9160 9165 9170 9175 9180 9185 9190 9195 9200 9205 9210 9215 9220 9225 9230 9235 9240 9245 9250 9255 9260 9265 9270 9275 9280 9285 9290 9295 9300 9305 9310 9315 9320 9325 9330 9335 9340 9345 9350 9355 9360 9365 9370 9375 9380 9385 9390 9395 9400 9405 9410 9415 9420 9425 9430 9435 9440 9445 9450 9455 9460 9465 9470 9475 9480 9485 9490 9495 9500 9505 9510 9515 9520 9525 9530 9535 9540 9545 9550 9555 9560 9565 9570 9575 9580 9585 9590 9595 9600 9605 9610 9615 9620 9625 9630 9635 9640 9645 9650 9655 9660 9665 9670 9675 9680 9685 9690 9695 9700 9705 9710 9715 9720 9725 9730 9735 9740 9745 9750 9755 9760 9765 9770 9775 9780 9785 9790 9795 9800 9805 9810 9815 9820 9825 9830 9835 9840 9845 9850 9855 9860 9865 9870 9875 9880 9885 9890 9895 9900 9905 9910 9915 9920 9925 9930 9935 9940 9945 9950 9955 9960 9965 9970 9975 9980 9985 9990 9995 9999

If a run-up phase precedes the continuous operation of the motor, then the overload protection may be designed so that the comparison of the nominal operating speed and the actual speed is first able to be initiated and carried out after a run-up phase of a predefined duration has expired, so that an inadvertent shut-down does not occur during this operating phase. The run-up phase may be preset by the control unit, it being possible to use the amplitude of the pulses and the pulse width of the PWM control signals, as well as their commutation frequency and the like as parameters. The run-up phase of the motor is able to be initiated with the switch-on of the control unit and/or the semiconductor output stages, and/or the input of a setpoint value for the control unit.

The invention is explained more precisely with reference to an exemplary embodiment shown in the Drawing, in which:

Figure 1 shows a block diagram of the functional units of the motor; and

Figure 2 shows a characteristics field stored in the control unit.

As the block diagram according to Figure 1 shows, the motor unit includes an electronic control unit STE which is assigned a comparator unit VE. For a desired continuous operation, a correspondingly adjusted setpoint value N_{set} is specified to this control unit STE.

Examination will now be made of the manner in which the width of the PWM control signals is determined.

known manner and supplied as a signal to a comparator
unit VE which may be integrated into control unit STE.
Stored in control unit STE is a motor characteristic
curve which allows the derivation of a nominal operating
speed n_x for each setpoint value $N_{setpoint}$. This nominal
operating speed n_x is obtained more or less exactly in the
case of the predefined setpoint value $N_{setpoint}$ if control
unit STE, semiconductor output stages EST and motor M are
operating correctly, and no conditions exist which lead
to a drop in actual speed N_{actual} .

Nominal operating speed n_x , like actual speed N_{actual} , is
supplied to comparator unit VE, and a speed deviation ΔN
is ascertained. If actual speed N_{actual} is more than a
15 predefined or predefinable speed deviation ΔN below
expected nominal operating speed n_x , then a fault exists
which can lead to an overload during continuous
operation. Therefore, comparator unit VE generates a
switch-off signal AB with which control unit STE and/or
20 semiconductor output stages EST can be switched off, as
the contacts off in the electric circuit of supply
voltage U_{batt} indicate.

If setpoint value $N_{setpoint}$ is changed, then PWM control
signals pwm, and therefore actual speed N_{actual} of motor M
change, as well. A correspondingly new nominal operating
speed n_x is supplied to comparator unit VE, and the
comparison is carried out in the same manner for the new
continuous operation with altered speed.

30 The switch-off of control unit STE and/or of

N_{setpointv} and the existing magnitude of supply voltage u_x. The comparison by comparator unit VE may be carried out continually during the continuous operation, or repeated at time intervals. In addition, the overload protection by the comparison and the shutdown may first be switched to effective after reaching the nominal operating speed specified by the setpoint value, i.e. after a predefined or predefinable run-up time has expired. In this context, the run-up time may be started with the switching-on, that is to say, with the feeding of supply voltage u_x to control circuit STE and/or to semiconductor output stages EST, and/or with the application of a predefined setpoint value N_{setpointv}, to control unit STE.

Nominal operating speed n_x, derived and calculated by control unit STE, is a function not only of existing supply voltage u_x with its limiting values u₁ and u₂, but also of stored speeds n₁₁, n₁₂, n₂₁, n₂₂ of the corner points of characteristics field KF, as the specification n_x=f(N_{setpointv}, u₁, u₂, n₁₁, n₁₂, n₂₁, n₂₂) in the Figure indicates, and as is clarified later.

As the three-dimensional characteristics field KF according to Figure 2 shows, the voltage range from U_{max} to U_{min} is plotted in the x-direction, while the pulse width from pwm_{min} to pwm_{max} extends in the z-direction. In the exemplary embodiment, U_{max} = 13V and U_{min} = 8V are selected, and the pulse width has a range from pwm_{min} = 60% to pwm_{max} = 100%. For the smallest supply voltage, given pwm_{min} = 60% and pwm_{max} = 100%, nominal operating speeds of n₁₁ = 50 min⁻¹ and n₂₁ = 1800 mm⁻¹

operating speeds n₁₂ to n₂₂ define the four corner points P1 to P4 in three-dimensional characteristics field KF.

and n_{1x} , n_{2x} and n_{3x} , and n_{4x} and n_{5x} , respectively, permit the formation of a grid which, for existing supply voltages U_x and pulse width pwm_x corresponding to a setpoint value, allows the derivation of allocated nominal operating speeds n_x on straight line $n_{1x} - n_{2x}$.
5 Thus, given a supply voltage of $U_x = 10.5V$ and a pulse width of approximately 87%, a nominal operating speed of approximately 1800 min^{-1} can be interpolated from characteristics field KF.

10 This characteristics field KF is valid for a specific motor for a predefined, constant load. For another load, a characteristics field KF valid for it can be stored in control unit STE.
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As the three-dimensional characteristics field KF according to Figure 2 shows, supply voltage u_x having the voltage range from smallest supply voltage $u_1 = 8V$ to greatest supply voltage $u_2 = 13V$ is plotted in the x-direction. In the z-direction, pulse width pwm of the PWM control signals is predefined, which may extend from minimal pulse width $pwm_1 = 60\%$ to maximum pulse width $pwm_2 = 100\%$. Given a preselected load of the motor, four limit operation cases are ascertained with u_1 and pwm_1 , u_1 and pwm_2 , u_2 and pwm_1 , as well as u_2 and pwm_2 , which lead to nominal operating speeds $n_x = n_{1x}$, n_{2x} , n_{3x} and n_{4x} , and consequently define characteristics field KF according to Figure 2.
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30 If motor M is loaded with a different load, then a similar characteristics field KF results having new

15 for exemplarily and element shown in Figure 2:

$n_{12} = 150 \text{ min}^{-1}$ at $u_2 = 13V$ and $\text{pwm}_1 = 60\%$
 $n_{21} = 1800 \text{ min}^{-1}$ at $u_1 = 8V$ and $\text{pwm}_2 = 100\%$
 $n_{22} = 2900 \text{ min}^{-1}$ at $u_2 = 13V$ and $\text{pwm}_2 = 100\%$

5 Characteristics field KF can be represented as a grid, the connecting lines between corner points n_{11} and n_{12} , and n_{21} and n_{22} , respectively, as well as n_{11} and n_{22} , and n_{12} and n_{21} , respectively, specifying the gridding, and as is shown, for an existing supply voltage u_x , permitting the
10 derivation of allocated nominal operating speed n_x in the case of existing PWM control signal pwm_x . PWM control signal pwm_x is allocated to predefined setpoint value $N_{\text{setpointv}}$.

15 As grid line $n_{x1} - n_{x2}$ shows, in the case of $u_x = 10.5V$ and a pulse width of $\text{pwm}_x \approx 87.5\%$, the derivation of nominal operating speed n_x leads to a value of approximately 1800 min^{-1} .

20 To calculate nominal operating speed n_x allocated to a setpoint value $N_{\text{setpointv}}$, one proceeds as follows:

$$stg1 = \frac{n_{12} - n_{11}}{u_2 - u_1} \quad stg2 = \frac{n_{22} - n_{21}}{u_2 - u_1}$$

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$$n_{1x} = n_{11} + stg_1 * (u_x - u_1)$$
$$n_{2x} = n_{21} + stg_2 * (u_x - u_1)$$

$$n_{x1} = n_{11}, \quad n_{x2} = n_{11} + (stg_1 - stg_2) * (u_2 - u_1)$$

Therein:

stgi -
stg2 -
stgs3 -

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$$n_v = n_{lv} + stg_3 * (pwm_v - pwm_l)$$

Since computer-internally, work is not done with the speed, but rather with its reciprocal value, the above equation for calculating surface point n_x must be changed around accordingly. With $T_x = a/n_x$, it follows that:

10

$$\frac{a}{T_x} = n_{lv} + stg_3 * (pwm_v - pwm_l)$$

$$T_v = \frac{a * (pwm_l - pwm_s)}{\left((stg_1 + stg_2) * u_v - n_{21} + n_{11} + (stg_2 - stg_1) * u_1 \right) * pwm_v + \left(pwm_1 * stg_2 - pwm_2 * stg_1 \right) * u_v + pwm_1 * (n_{21} - u_1 * stg_2) + pwm_2 * (stg_1 * u_1 - n_{11})}$$

15

In the formula above, only supply voltage U_v and the pulse width of output stage control pwm_v are variable. The remaining factors may be stored as fixed parameters in the ROM or EEPROM. Following is once again the same formula with the variable names used in the program code.

20

$$v_{tx} = \frac{K_{ZAEHL_1}}{\left((K_{NENN_1} * v_{ubat} + K_{NENN_2}) * v_{pwm_endst} + K_{NENN_3} * v_{ubat} + K_{NENN_4} \right)}$$

During the programming at the rear end of the assembly line, the corresponding parameters can now be transferred from the test stand into the EEPROM of the motor control

$$K_{NENN_1} = (stg_1 - stg_2)$$

$$K_{NENN_2} = -n_{21} + n_{11} + (stg_2 - stg_1) * u_1$$

$$K_{NENN_3} = (pwm_1 * stg_2 - pwm_2 * stg_1)$$

$$K_{NENN_4} = pwm_1 * (n_{21} - u_1 * stg_2) + pwm_2 * (stg_1 * u_1 - n_{11})$$